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16. Abstract

The history of the Bionics Laboratory of Kazan' University Physics Faculty is briefly outlined. An account is given of the organization of the Laboratory, past accomplishments of the Laboratory are reviewed, and current and future problems of its activity are considered.

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BIONICS: THEORETICAL AND PRACTICAL PROBLEMS

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The bionics problems scientific research laboratory at the Physics Faculty /41* of Kazan' University was organized in 1969 on the basis of a bionics group which had existed earlier in the Department of Radio Electronics. This group provided initial formulation of the questions to be studied and preliminary approval of certain aspects of the problem now being developed. The laboratory was assigned the task of performing a number of concrete research projects in one of the basic directions of bionics, that of study of the processes of stimulation and excitation, and of constituting itself a base for specialized training of students and training of postgraduate students in bionics.

Certain difficulties arose at the very beginning of the work in our laboratory. It was the first university laboratory dealing with such questions, and in determining its structure and selecting specialists we were unable to avail ourselves of the experiences of other organizations. Study of the experience of sections with a different specialty was inadequate because of the specific nature of bionic research. The difficulties were heightened by the at first narrowly utilitarian concept of the subject itself of bionics, and the inadequate elaboration of the theoretical questions and the organizational principles governing this science.

All this required consideration in the first approximation of certain questions of a methodological nature. It was additionally necessary to substantiate the field of research selected, to determine the fundamental and long-range questions the elaboration of which will ensure development of the field of bionics at the university, and at the same time to demonstrate the possibility of obtaining a sufficiently extensive practical "yield" from such

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*Numbers in the margin indicate pagination in the foreign text.

study, the need being taken into account of linking it closely to the educational process, scientific research by students.

We believe that an account of how all these matters were resolved might be of a certain amount of interest to our colleagues.

Elaboration of the theoretical problems of bionics is an urgent task. This task is set both by the practice of bionic research and by the logic of development of science as a whole.

In our specific-problem laboratory an attempt was made to examine the methodological questions of bionics on the basis of the classic propositions concerning the forms of motion of matter. This led to the formulation of the concept of bionics as a science which ultimately strives to reproduce individual properties, the mechanisms of the biological form of the motion of matter, which are the most complex in nature, in artificial systems. An approach such as this defines with sufficient clarity the strategy of bionics and of those sciences which apparently will branch out from it in the future. At the same time it is apparent that the development of bionics is an objective process and the normal result of previous stages in the development of science and technology which previously have not formulated from the cognitive and applied viewpoints the question of the biological form of motion in systems devised by man. It is further apparent that the initial widespread concept of bionics has a sector studying animated nature in order to solve engineering problems is assigned its place as an important applied branch of bionics.

This concept of bionics permits consideration in the most general way of the extent of propagation of bionic simulation. Much research in the past concentrated on imitation of the geometric forms of individual representatives of the animated world. Further development of bionic research led to attempts to utilize in technology certain properties of individual organs and systems of the animal species known to us. These are currently the most widespread elaborations, which are figuratively termed "patents of animated nature". Systematic intensification of research leads to reproduction of the more common phenomena -- the laws governing the structure and functioning, to all animated nature at all levels of organization of the system -- in artificial systems (in technical ones in particular). The deep-seated qualities of animated

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nature, the intrinsic nature of motion in it, will in the future apparently be the object of transfer to engineering and technology as the necessary information is acquired in science.

These theoretical propositions have been reflected in choice of the orientation of work by our specific-problem laboratory, which has set as its main task study and simulation of certain patterns of functioning of the animated world.

In resolving the problems relating the structure of the laboratory and choice of specialists we have taken into account the circumstance that every bionic idea passes through three stages between its origination and its embodiment. The first, biological, stage involves study of the biological object from the viewpoint of the problem assigned. In the second, theoretical, stage these data are generalized and mathematical models and functional diagrams are constructed. In the third, applied, stage a technical embodiment is produced from the bionic idea.

Our specific-problem laboratory accordingly has three groups, biophysical, mathematical, and engineering and technical. They are made up of biophysicists and physiologists, mathematicians, physicists and physical chemists, and engineers who have been trained in the field of electronics and instrument engineering. It is important to note that all these specialists must adapt themselves to the complexity of bionics, to its way of thinking, and in the solving of common problems establish group cooperation and achieve understanding to some extent of each other's language and the nature and methods of work of all. Otherwise the activities of the bionics laboratory would become unproductive.

It is characteristic that fresh results are being obtained in all stages of bionic studies. This apparently is to be ascribed to the new three-stage technology. For example, in biological study of stable and variable indices of the electric excitability of muscles in man our associates have discovered a new clinical indicator for progressive muscular dystrophy. The valuable results of the theoretical stage are represented by the construction of models and formal establishment of one or another biological mechanism, together with

recommendations for the entire class of technical or other systems. As regards the applied stage, its "yield" is channeled concretely into one or another field of engineering and technology.

The basic problem with which our laboratory is concerned may be stated as "study of the processes of excitability and stimulation and their simulation for applied purposes." We know that there are many mechanisms of excitability and stimulation. Hence it was necessary to work out the interrelated ramifications of the problem. A systematic development such as this is advantageous in that it covers the different levels of organization of the animated world and incorporates the mechanisms of excitability and stimulation known at the present time, and so in each given period enables researchers to concentrate attention on a definite question actually susceptible of bionic simulation because of the degree of "maturity" and the availability of personnel and equipment required, one from which a "yield" may be obtained within a short period for theory and practice.

The laboratory, taking all this into account, initially concerned itself with study and applied simulation of the threshold mechanisms of excitation of /43
nerves and muscles. Certain mechanisms of adaptation and memory were subsequently included in the sphere of research. The general goal was elaboration of a bionic theory of "trigger" systems based on the laws of excitation of excitable living structures.

We again divided the program of elaboration of the theory of "trigger" systems chronologically into three periods: study of biological objects and construction of models of varying nature for the purpose of ascertaining the applied value and ranges of applicability of the mechanisms and indices of excitability in engineering and other fields; elaboration on this basis of a general bionic theory cleverly combining the particular application; and applied work consisting in selection from among the possibilities determined in the first stage of one or two objects for concrete elaboration and adoption.

At first we conducted intensive research with hydraulic, electronic, and physicochemical analogue models. In the process the parameters adopted in physiology which characterize the work of living "trigger" systems -- nerves, muscles, receptors -- were systematized, the missing links were determined,

and new indices were elaborated. The direct practical utility of a number of models was detected at this point. The attempt at imitation of the energy and structural characteristics of the animated world as required by the bionicist led to study of the kinetics of energy transfer in the case of excitation, as well as to parallel study of the changes in electric excitability and the coefficients of self-diffusion of interstitial proton carriers by the spin echo method.

Mathematical study was subsequently made of the characteristic curve describing the conditions of threshold reactions of a nerve to isolated excitation, and an analysis was made of adequate conditions in the work of nerves and muscles ("minimum energy" conditions), and the stable and variable parameters in nerve adaptation were ascertained.

This research led to the elaboration of a number of practical recommendations. For example, a method was devised for finding the optimum operating conditions based on input parameters and the cases in which a differential equation for the motion of a system cannot be set up because of the complexity of the phenomenon. A method was proposed for evaluating the operating conditions of a controlled motor and the electric drives of production mechanisms characterized by cyclic operation; excitation mechanisms were applied to the description, analysis, and optimization of the conditions of actions of chemical substances on the living organism; and so forth.

Thus the problem with which we are concerned has a broad profile and far-reaching implications; this is of importance for development of the bionic orientation of research. At the same time the problem is of considerable practical importance. In this context mention should be made along with the foregoing of work on a pneumoneuron, an artificial muscle, and memory cells, and on original instruments constructed in the laboratory for investigation of excitability.

The research conducted by the laboratory staff, with the participation of postgraduate students and bionics students, has been embodied in published papers, records, dissertations, inventions, reports, models, and devices. During the four years of existence of the special-problem laboratory a monograph

has been published, two issues of the collection *Issledovaniya po Bionike* [Bionics Research] have been printed, about 70 articles have been published, and 10 author's certificates have been obtained. The number of invention registration applications exceeds 30. Members of our staff have delivered reports on their work at scientific congresses, conferences, and symposia. Four doctoral dissertations have already been defended.

A few words should be said about the link with production. Our experience has shown that this link, while not appreciably distracting the attention and efforts of the laboratory from its immediate tasks, makes it possible to establish some contact with production personnel and creates suitable conditions for continuing discovery of areas of useful application of our ideas in the system of plant engineering and technology. /44

However, it is necessary to stress here the unique character of the "yield" of bionics to engineering and production. It consists in the fact that in the concrete utilization of a particular recommendation deriving from bionic research there is no longer any need to mention the living prototype from which the idea was originally borrowed. Thus, our recommendations concerning the conditions of minimum expenditure of energy in electric motors, those relating to the description, analysis, and determination of adequate conditions in devices for electrochemical treatment of parts, those regarding control systems, and others, being derived from analysis of "actuation" of nerves and muscles, no longer require bionic substantiation in use at factories.

This characteristic often induces a person not familiar with the structure of bionics to ignore its priority to assume that a particular development is not bionic in nature. All this creates certain difficulties in substantiating the harmony of our production activities with the problems of bionics.

A highly important matter is that of the relationship of the laboratory's work to the educational process. We always keep in mind that our unit is a university organization.

At Kazan' University the education of students in bionics began as long ago as 1963. It is being imparted in accordance with a curriculum expressly prepared for the group of bionicists. The curriculum is improved from year to

year on the basis of our experience, the continuing increase in the general requirements set for university graduates being taken into account. In 1972 we graduated 21 specialists and this year will graduate 14. There are now 12 fifth-year students in our group.

The specialized course which we give, in accordance with the stages of bionic research, consists of a cycle of biological, mathematical, and engineering subjects. Just as in the research work, the problem of excitation and stimulation is a prominant feature of the entire educational process. It is this problem which determines the basic content of the text books scheduled for publication.

An important element in the educational process is amplification of the ideological content of the specialist's education. In this context the specialized course includes questions of the methodology of bionics. All this is supplemented by participation by the students in the work of a philosophy seminar by teachers of the physics faculty and a methodological seminar of the bionics problems laboratory entitled "The Biological Form of the Motion of Matter".

We feel it to be our duty to provide the student with an array of fundamental knowledge so that on its basis the graduate will be able to adapt himself to the great breadth of the concepts of bionics and the rapidly changing, dynamic conditions under which he will have to work. It must be said that our students are proving themselves in their work as specialists to be fairly well oriented in all three spheres of activity represented by the stages of bionic research (we have discussed this at length in an article published in *Vestnik Vysshey Shkoly*, No. 4, 1973).

We employ various methods to bring the students into contact with the science and to broaden the scientific investigation in which they are engaged. The students join the research, development, and production groups of the laboratory to perform their educational assignments and to conduct independent research. It may be said in passing that this has a positive effect on the entire work of this scientific organization. The majority of the laboratory personnel take part in the educational process by giving the students an account

of the theoretical and applied aspects of our research. Also of considerable importance is the participation by the students and postgraduate students in the work of the scientific seminars of the laboratory.

We have a student design office. It includes students of the physics, mechanics and mathematics, and biology and soil faculties of the university. /45 Papers by our students are delivered at student scientific conferences and are displayed at national exhibits. In 1972 six papers were entries in a national competitive review.

In conclusion we should like to take up certain problems facing our bionics laboratory as a division of the university.

Above all we believe that in the future the organizational structure of the laboratory should be improved and its staff should be enlarged by addition of our own graduates. The most effective way of solving this problem is training staff personnel expressly for purposes of bionics.

Another problem is that of steadfast adherence to the credo of bionics by not gravitating toward isolated biological and engineering groups having no relation to the three-stage technology of bionic works and solving problems outside the stream of feedback of the biological, theoretical, and applied stages.

In addition, despite the fact that the laboratory has recently made individual recommendations to the fields of engineering and technology, amplification of the applied aspect of the work continues to be a highly important task. In this context we must systematically bring to fruition the development of new methods and devices proposed by personnel of the laboratory. In order to do this it is important to strengthen the contact between the laboratory and production organization.

The long-range tasks of the creative laboratory group consist in finding approaches toward and ways and means of reproducing individual deep seated properties of animated nature and the intrinsic character of motion in the latter. It is important here to find methods of embodying in models another important credo of bionics, the unity of functions and structure represented in such perfection in living systems.

We can assume that with the advancement of knowledge bionics, by proceeding along this line of investigation, will construct artificial systems the characteristics of which will increasingly and more fully approximate the characteristics of animated nature. The fact that the staff of the bionics problems laboratory is deeply convinced of this represents an important stimulus in its activities.

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